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IMPROVED METHOD FOR FILTERING A LIQUID METAL ON A BED OF REFRACTORY PARTICULATE MATERIAL

Field of the Invention

Technical field

The invention relates to an improved method for filtering a liquid metal, in particular aluminium, magnesium, or their alloys on a thick bed of refractory gravel.

Description of Related Art

State of the art

The filtering of liquid aluminium on a thick bed of gravel made of sintered alumina, so-called tabular alumina which is an alpha alumina, generally in the form of beads or crushed grains, is known, for removing solid or liquid inclusions from it. It is very important to be able to improve this removal in particular when aluminium is used for obtaining very thin sheets in order to reduce the risk of waste material; indeed, the thinner the produced sheet, the more it becomes necessary to remove the small sized inclusions, in addition to the large ones, because they produce defects which become detrimental.

The bed of sintered alumina gravel generally has a thickness of the order of 40 cm. The purification rate of liquid metal after filtering inclusions by this type of alumina is limited; thus said metal may further contain after filtration up to 10,000 particles of a size greater than 20 µm per kg, even for a residence time which generally is between 100 and 500 secs, wherein said purification rate is very variable depending on the size of the particles and from one casting operation to another. Furthermore, it should be noted that this type of alumina is expensive.

The applicant has thus tried to reduce the amount of inclusions present in the filtered liquid metal by more particularly concerning herself with improving the removal of small size inclusions. She has also tried to reduce the cost, and more generally improve the performances of the liquid metal filtering process through a bed of particulate material, while trying to find a solution to the problem of recycling said bed of particulate material.

Summary of the invention

Description of the invention

The invention is a method for filtering a liquid metal wherein said liquid metal flows through a thick bed of refractory particulate material having an open porosity between 5 and 30%.

This method is essentially applied to aluminium, magnesium or their alloys.

Porosity, which corresponds to the porous volume of the grains of the bed (surface porosities and internal porosities) is measured by mercury porosimetry; it is due to pores of a diameter essentially greater than 10 µm and generally less than 200 µm in order to maintain good resistance to erosion. The particle size is preferably between 0,2 and 20 mm and the bed has a thickness of 4 to 40 cm. The residence time of the liquid metal in the gravel bed may be of the same order of magnitude as that used for the tabular alumina gravel but it is remarkable to note that a purification, at least equivalent, or even superior, to that obtained with said alumina, is obtained for residence times less than 200 secs, or even less than 50 secs. With such short residence times, the size of the industrial facilities may be

significantly reduced, while maintaining a same filtration efficiency.

As a comparison, tabular alumina gravel has a very low porosity generally less than 3% due to very fine pores less than 10 µm in majority.

The material used in the invention advantageously is an alumina. According to the preferred embodiment of the invention, said refractory material is an electrofused corundum obtained by fusing an alumina in an arc oven, followed by a casting process, preferably in moulds, by adjusting the cooling and solidification state in order to obtain the desired open porosity, and by a crushing and/or grinding process, for example in a roller or hammer mill, wherein the obtained gravel is then screened to the desired size and dust removed. Crystallization modifiers such as F, B, Y, MgO or SiO_2 may be added for controlling the porosity. Preferably, white corundum is used in order to prevent any risk of chemically contaminating the liquid metal.

The removal rate of the inclusions is always greater than 95%, even greater than 97%, regardless of the size of said inclusions, which also results in a significant reduction in the presence of particles with small dimensions.

It is important to note that even if it is always possible to use a long residence time in order to improve the removal rate of the inclusions, with the invention reduced residence times may be used while maintaining a quality level at least equal, or even superior to that observed with other particulate materials and a remarkable constancy from one casting process to another, which for example is not the case with tabular alumina. The possibility of filtering with

reduced residence times also results in a given thickness of the gravels, by the possibility of increasing the metal flow rate (or the filtration rate) with equal efficiency. This possibility may also limit the release of inclusions during surges of the metal flow rate.

Thus, the residence time may be as reduced as 1 sec, preferably at least 2 secs, and still preferably at least equal to 5 secs; it is generally less than 500 secs, preferably less than 200 secs, and preferably still less than 100 secs, and is advantageously located between 2 and 200 secs or better between 2 and 100 secs, or even between 5 and 100 secs, the shortest residence times being determined by the level of the desired removal rate and the accepted risk of release of the inclusions.

As an illustration, the number of particles present in the filtered metal does not generally exceed 600 particles with a size greater than 20 µm per kg of filtered liquid metal, the amount of smaller particles being reduced by the same factor. It appears that not only the fixing of the inclusions is better carried out but even that no release occurs.

It seems that the presence of the required minimum porosity plays a primordial role for increasing the filtration efficiency, the retention rate for the inclusions, the filtration rate, or for reducing the size of retained inclusions and for preventing their release.

Also, the retention capacity of the inclusions in corundum is larger than in tabular alumina, i.e., at a constant purification rate of the liquid metal, the lifetime of the filters is increased. The frequency of

operations for changing the filtering bed is then reduced, so that stops in production may also be limited.

It may also be believed that other parameters may play an important role like roughness or surface chemistry which may increase wettability by the liquid metal and the retention capacity (or adhesion) of the inclusions on the gravel. The phenomena involved may be different from those occurring with tabular alumina of very low porosity. A partly intragranular filtration may in particular occur whereas for a tabular alumina, pores of a diameter less than 10 µm are not accessible to liquid aluminium in the normal operating conditions.

The fact of being able to use high filtration rates while improving the purification rate and retention rate may increase productivity, reduce the size of filtering facilities, reduce consumption of filtering medium and thus obtain a reduction in costs all the more significant as corundum is itself less expensive than tabular alumina.

Further, corundum provides the advantage of being able to be easily recycled by re-manufacturing it through simple fusion whereas for tabular alumina, if the intention is to avoid an expensive re-manufacture, a complex regeneration treatment must be performed as it generally comprises the combination of a treatment with different aqueous solutions, which are as many effluents to be treated and/or recycled, and a regeneration heat treatment.

Said bed may optionally be reinforced in order to facilitate its handling.

The following example illustrates the invention by comparing it to the state of the art.

Two filtering beds were successively used in the same facility for performing several castings each.

The first bed, according to the prior art, is based on tabular alumina beads with a particle size of 3/6 mesh, i.e. between 3.35 mm and 6.70 mm, and with a porosity of 2.8% mostly due to pores with a diameter less than 7 µm; it has a thickness of 40 cm. Measurement of the specific surface, according to the multi-molecular adsorption measurement method known as the BET (Brunauer, Emmet and Teller) method, gave a value of 0.012 m^2/g for this bed.

The second bed, according to the invention, is a white corundum (with a purity higher than 99.6%) with porosity of 10.7% mostly due to pores with a diameter between 10 and 250 µm, its particle size is between 3 and 6 mm and the bed has a thickness of 40 cm. It is obtained by casting liquid alumina into metal ingot moulds, wherein the cooling and solidification rate is 50 to 100°C/hr, by crushing the solidified product and then grinding it in a roller mill and by screening it between sieves with 3 and 6 mm apertures. The BET specific surface of this bed was 0.09 m^2/g. The particles of the bed were rather of an acicular shape, even needle-shaped in certain tests.

The porosity distribution of the bed's particles according to the prior art (curve A) and according to the invention (curve B) is illustrated in Fig. 1. Fig. 1a gives the porous volume V (in cm^3/g) versus the pore diameter ∅ (in µm). Fig. 1b gives the same pore distributions as Fig. 1a in cumulative form (cumulative pore distributions).

The liquid metal used is an aluminium-magnesium alloy (1.2%) wherein known additions of inclusions with

a size less than 120 µm were made in order to obtain between 10,000 and 35,000 inclusions/kg of metal depending on the castings. The residence time of liquid aluminium in the filtering bed is 100 secs during each of the castings.

Counting of the inclusions is carried out by means of a LiMCA (Liquid Metal Cleanliness Analysis) apparatus marketed by BOMEM and implementing in liquid aluminium the well-known counting method of the so-called Counter Coulter type which measures both number and size of the particles by measuring electric resistance when the latter pass through a calibrated port.

The tables below give for each casting, the inclusion removal rate, in %, observed during the casting depending on the size of the inclusions. Table 1 corresponds to tests according to the prior art, Table 2 corresponds to the tests according to the invention.

Table 1: Inclusion removal rate after filtration on a tabular alumina bed (comparative tests)

Inclusion size µm	20-40	40-60	60-80	>80
Casting 1	77	73	77	87
Casting 2	95	93	91	94
Casting 5	88	90	87	92
Casting 6	84	90	92	98
Average	86	87	87	93

It is seen that in these tests, dispersion of the results is significant both from one casting to another and depending on the particle size and that on average,

removal rate is insufficient as it does not exceed 93% for the largest inclusions. The randomness of the inclusion removal rate is particularly detrimental because it considerably increases the risk of waste material when thin or very thin metal sheets are obtained subsequently.

Table 2: Inclusion removal rate after filtration on a corundum bed according to the invention

Inclusion size µm	20-40	40-60	60-80	80-100
Casting 1	98	99	98	97
Casting 2	99	99	100	99
Casting 3	98	98	96	99
Casting 4	99	99	99	98
Casting 5	99	99	98	97
Average	99	99	98	98

It is observed that the filtering result is both excellent in homogeneity and in level as the removal rate is on average at least 98%. In particular, the smallest particles have been very well removed.

Fig. 2, which gives the filtration efficiency E (in %) versus the residence time T (in seconds) for a filter according to the prior art (curve A) and according to the invention (curve B), shows that filtering beds according to the invention maintain a very high filtering efficiency for residence times less than 200 secs, whereas the efficiency of filtering beds of the prior art are substantially reduced for residence times less than 200 secs. The residence time corresponds to the equivalent drum-vacuum filtering

rate, i.e. it corresponds to the minimum residence time calculated from the metal flow rate as if it were a laminar flow. In spite of a close, even lower specific surface than that of the bed of the prior art, the bed according to the invention did exhibit larger filtration efficiency.